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Attorney Docket No.: 2935/PDC/ICT/JB

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Box Patent Application
Commissioner of Patents and Trademarks
Washington, D.C. 20231

JC518 U.S. PTO 09/162103 09/28/98

Re: Inventor(s):: Deiter WINKLER, Hans-Peter FEUERBAUM, Joseph BACH
Title: CHARGED PARTICEL BEAM MICROSCOPE WITH MINICOLUN

Transmitted herewith is the patent application identified above, including:

X Specification, claims and abstract, totaling 14 pages.

X Drawings totaling 5 pages, __ Formal X Informal

X Information Disclosure Statement (37 CFR 1.98)

X Cited References

FEE CALCULATION

Fee Items	Claims Filed	Included With Basic Fee	Extra Claims	Fee Rate	Total
Total Claims	17	-20=	0	X$22.00	--
Independent Claims	3	-3=	0	X$80.00	--
Basic Filing Fee				$790.00	$790.00
TOTAL FEES					$790.00

XX The Commissioner is hereby authorized to charge $790.00 to Deposit Account No. 01-1651.

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~~Barbara Holt~~

BETH MULCAHY

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Registration No. 25,436

CHARGED PARTICEL BEAM MICROSCOPE WITH MINICOLUMN

BACKGROUN OF THE INVENTION

1. Field of the Invention

The invention relates to charged particle beam microscopes and, particularly, to arrangements for equipping such a microscope with a minicolumn.

2. Discussion of Related Art

Charged particle beam microscopes, such as an electron microscope, are well known in the art, and are widely used during the manufacture of semiconductor wafers. For ease of discussion, the remaining disclosure makes reference to electrons as the charged particles; however, it should be appreciated that the discussion is equally applicable to other charged particles. The elements of a conventional electron microscopes which are of particular relevance here are depicted in Figure 1. Specifically, a vacuum chamber 10 houses an x-y stage 20 upon which the wafer 40 is placed by a robot (not shown). The chamber 10 is evacuated via outlet 70. The wafer 40 is introduced into the chamber 10 via a load lock 30 so as to avoid having to evacuate the chamber 10 each time a wafer is loaded.

An electron column 50 is hermetically attached to the chamber 10. The column 50 houses the electron source and all the necessary electron optics (not shown). The column 50 is evacuated via outlet 60. The diameter of a conventional column is roughly 6-10 inches, while its height is roughly 15-30 inches. The conventional column is capable of providing an electron beam of sufficiently small diameter for wafer and reticle inspection, review and metrology.

One disadvantage of the prior art design is that whenever the column requires a repair which necessitates its removal from the chamber or breaking the vacuum in the column, the vacuum of the chamber is also broken. Breaking the vacuum in the chamber necessarily means that the microscope will be out of service for several hours. Another disadvantage is the requirement for separate vacuum systems for the column and the chamber, which increases the complexity and price of the system, while adversely affecting its reliability and stability.

Recently, a new type of column has been developed, and is generally referred to as a "minicolumn." A cross section of a minicolumn investigated by the current inventors is depicted in Figure 2. In Figure 2, element 200 is the electron source (preferably a shottky emitter), 210 is an aperture (suppressor), and 220 generally designates the lens arrangement. More specifically, lens arrangement 220 comprises three lenses 230 made of a conductive material and insulating spacers 240 interposed between the lenses 230. Ordered from the emitter, the lenses 230 comprise an extraction lens, a focusing lens, and an acceleration lens, respectively.

Notably, the diameter and height of such a column is measured in single-digit centimeters. More specifically, the diameter of the lens arrangement depicted in Figure 2 is on the order of 3 centimeters, while its height is on the order of 1 centimeter. While this column is remarkably smaller than the conventional column, it provides an electron beam which has small diameter and was determined by the present inventors to be suitable for use in electron microscopes. Further information

regarding the study of the minicolumn is presented in F. Burstert, D. Winkler and B. Lischke, Microelectronic Engineering 31 (1996) 95; and in Miniature Electrostatic Lens for Generation of a Low-Voltage High Current Electron Probe, C. D. Bubeck, A. Fleischmann, G. Knell, R. Y. Lutsch, E. Plies and D. Winkler, Proceedings of the Charged Particle Optics Conference, April 14-17, 1998.

SUMMARY OF THE INVENTION

Accordingly, the present invention provides arrangements for installing minicolumns onto charged particle microscope, especially electron microscopes, while providing synergetic advantages over the prior art column arrangement. That is, the disclosed arrangements provide advantages in addition to the advantages of the minicolumn *per se*.

According to one set of embodiments of the invention, a second load lock is provided on the microscopes vacuum chamber. The second load lock is used to introduce the minicolumn into the chamber without having to break the vacuum in the chamber. Thus, a technician can replace the minicolumn without having to break the vacuum in the chamber.

According to another set of embodiments, the minicolumn is situated inside the microscope's vacuum chamber. While this arrangement necessitates breaking the vacuum for each minicolumn service, it is still advantageous in that there is no need for separate vacuum system for the column. This is advantageous especially if more than one minicolumn is used inside the chamber.

Another advantage of the invention is that it provides arrangements for more than one minicolumn per microscope. This arrangement is especially advantageous for taking multiple perspectives simultaneously or for increasing the throughput.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 depicts relevant elements of a conventional electron microscope.

Figure 2 depicts a lens arrangement of a minicolumn investigated by the present inventors.

Figure 3A depicts an embodiment of an isolation valve arrangement in a closed position, while Figure 3B depicts the arrangement of Figure 3A in an open position.

Figure 4A depicts another embodiment of an isolation valve in a closed position, and Figure 4B depicts the embodiment of Figure 4A in an open position.

Figure 5A depicts an embodiment of a minicolumn within the microscope chamber, while Figure 5B depicts an embodiment of a plurality of minicolumns arranged inside the chamber at different angles.

Figures 6A and 6B depict embodiment using a turntable stage for reduced footprint.

Figure 7A depicts an arrangement of an arm having a plurality of minicolumns situated at different angles advantageous for defect review, while Figure 7B depicts an arm having a plurality of minicolumns at a single angle advantageous for sector-wise inspection.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figures 3A and 3B depict a first embodiment of an isolation valve for the minicolumn 300. Specifically, the vacuum chamber 310 is equipped with a valve 320 capable of hermetically sealing chamber 320 in the closed position. Minicolumn 300 is positioned inside a mini-environment chamber 330, which can be evacuated via outlet 335. In the exemplified embodiment, the mini-environment chamber 330 has collapsible walls 340, which are actuated by bellows 345. However, it should be appreciated that other solutions having rigid walls with means for elevating and lowering the columns are also workable.

During maintenance, the mini-environment chamber 330 is in its closed position. In the closed position, exemplified in Figure 3A, the bellows 345 are extended so as to raise the walls 340 to upright position. In this upright position, the minicolumn is extruded from the chamber 310 and valve 320 is closed to maintain the vacuum level inside the chamber 310. When maintenance is completed, the mini-environment chamber 330 can be evacuated via outlet 335 and, when the evacuation is completed, the valve 320 can be opened and the minicolumn lowered to the chamber 310.

Specifically, Figure 3B exemplifies the situation during operation of the microscope. When the mini-environment chamber 330 has been evacuated and the valve 320 opened, the bellows collapse the walls 340 so as to introduce the minicolumn into the chamber 310, close to the stage 315. Unless the minicolumn malfunctions, there is not need to revert to the position shown in Figure 3A, and the

microscope can be maintained in the position shown in Figure 3B. However, if the minicolumn requires maintenance or replacement, the bellows 345 are extended to raise the walls 340 and extrude the minicolumn 300 from chamber 310; the valve 320 is closed; and the mini-environment chamber 330 is brought to atmospheric pressure via outlet 335.

Another embodiment for isolation valve is depicted in Figures 4A and 4B. Minicolumn 400 is situated inside a mini-environment chamber 430 that is open at its bottom to chamber 410. Mini-environment chamber 430 has an outlet 435 which, in this example, is connected to the outlet 445 via vacuum valve 440. Thus, mini-environment chamber 430 and chamber 410 can be connected to the same vacuum pump (not shown). However, it should be appreciated that outlet 435 can be connected independently to a separate vacuum pump. Isolation valve 450 is pivoted on shaft 455, which is capable of elevation motion, i.e., in the Z direction.

During operation (depicted in Figure 4B), isolation valve 450 is swiveled away from the opening of mini-environment chamber 430, and the shaft 455 is in its upper-most position so as to place the isolation valve 450 out of the working area of the microscope. Preferably, stage 415 is equipped with actuators for Z motion so that during operation the distance between the minicolumn and the specimen can be adjusted for proper imaging. Such stages are well known in the art and will not be described here. If the outlet arrangement depicted in Figure 3B is used, then during operation valve 440 can be maintained open so that vacuum pump operation maintains vacuum in both chambers 410 and 430.

When access to the minicolumn is required, the stage is lowered and the valve 450 is brought to its close position. For that operation, preferably the shaft 455 is lowered to its lowest position, the valve 450 is swiveled to its close position and the shaft 455 is elevated sufficiently to cause hermetic seal between the valve 450 and the opening of the mini-environment chamber 430. Then valve 440 can be moved to the open position so that mini-environment chamber 430 is brought to atmospheric pressure. Then the back plate 460 can be removed for access to the minicolumn. Preferably, the minicolumn itself is secured to the back plate 460 , so that it is removed together with the back plate 460.

Figure 5A depicts an arrangement of a minicolumn enclosed within the microscope chamber. Specifically, minicolumn 500 is positioned completely inside the chamber 510, so that no separate evacuation is necessary for the minicolumn 500. Preferably the stage 515 is capable of elevation motion to control the distance between the minicolumn 500 and the specimen. Here again, it is preferred that the minicolumn be attached to a back plate 560, so that removal of the back plate 560 would remove the minicolumn 500 as well. Such an arrangement is particularly useful for metrology, such as for critical dimension (CD) measurement microscopes. Also exemplified in Fig. 5A is an in-chamber integrated vacuum pump, which controls the vacuum inside the minicolumn 500.

Electron microscopes can also be used for review of locations on wafers which are suspected of having defects thereupon. In such application, it is particularly useful

to be able to scan the suspect area at different angles. A particularly elegant way of doing so using a conventional column is described in U.S. Patent No. 5,329,125 to Feuerbaum. In that patent, a system is disclosed which is capable of placing the column at any tilt between 0-45 degrees, without breaking the vacuum inside the column or the microscope chamber. Thus, one can take a picture at 0 tilt, and then tilt the column to a desired position and take another picture for added information. Notably pictures taken at a tilt tend to have more topographic information than those taken without tilt.

Figure 5B exemplifies a system having a plurality of minicolumns, and particularly suitable for an electron microscope review station. As shown in the Figure, a first minicolumn 500 is situated inside the chamber at zero tilt. A second minicolumn 520 is positioned at a first tilt θ and a third minicolumn is positioned at a second tilt ϕ. In the preferred embodiment, the tilt angles θ and ϕ are fixed and different from each other. Preferably the tilts are fixed at 30 and 60 degrees, respectively, or 30 and 45 degrees, respectively. However, as shown in Figure 5B, the tilts can be variable by, for example, pivoting the columns 520 and 525 about pivots 530 and 535, respectively.

It is well known that chamber size directly affects the quality of the vacuum maintained within the chamber and, consequently, can affect the reliability and "cleanliness" of the equipment. Additionally, large chambers require large footprint, which is of paramount consideration for fabrication plants, wherein clean-room real estate is at a premium. However, x-y stages generally require large chambers since

they require motion space that is at least twice the size of the largest specimen to be inspected. Considering that the semiconductor industry is moving towards a 300mm wafers, an x-y stage for such wafer can dictate a very large footprint.

Figures 6A and 6B depict embodiments which are particularly advantageous for reducing the footprint of the microscope. Specifically, Figures 6A and 6B depicts a minicolumn 600 attached to an arm 620, which is situated inside the chamber 610. Rather than an x-y stage, a turntable stage 615 is used. In Figure 6A the arm 620 is pivoted about pivot 625, while in Figure 6B the arm is attached to a linear carriage 635. In both cases, the arms 620 are capable of moving the minicolumn 600 through the entire radius of the stage 615. Through the rotational motion of the turntable stage 615, and the motion of the arm 630 (whether radial or linear), every location on the specimen can be reached in polar (r,θ) coordinates.

As noted above, it is desirable to be able to obtain images of the same spot using tilt. Figure 7A depicts a turntable arrangement similar to that depicted in Figure 6B, except that the arm 720 carries two minicolumns 700 and 705. In the exemplified embodiment, minicolumn 700 is situated with zero tilt, while minicolumn 705 is situated with a fixed tilt, preferably of 30 or 45 degrees. However, it should be appreciated that more than two minicolumns can be provided, and that the tilt can be variable rather than fixed.

It is also known to use electron microscopes to inspect wafers and reticles for defects. An exemplary system is disclosed in U.S. Patent No. 5,502,306 to

Meisburger et al. That system uses a single conventional column to scan the entire wafer/reticle for defects. The system is sold under the name of SEMSpec by KLA of San Jose California and is known to have a very slow throughput.

Figure 7B depicts an arm 740 structured to support a plurality of columns 745 positioned with zero tilt. The arm 740 is attached to a linear carriage 755. Such an arm can be installed in a chamber having a turntable stage for inspecting an entire wafer for defects. Specifically, the wafer is divided to concentric sectors corresponding to the number of minicolumns 745 attached to arm 740. Thus, as the wafer is rotated, the carriage 755 need travel only a length equal to the radial length of one sector. During such motion, each minicolumn 745 would scan its corresponding sector, thereby covering the entire wafer. Of course, an small overlap may be provided to ensure complete coverage.

While the invention has been described with reference to particular embodiments thereof, it should be appreciated that that other embodiments and modifications can be implemented without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. An electron microscope, comprising:

a main vacuum chamber housing a stage therein and connected to a vacuum pump;

a load lock for loading specimen into said main chamber; and,

a mini-environment housing a minicolumn.

2. The electron microscope of claim 1, wherein said mini-environment comprises an opening to the main chamber for introducing and extruding said minicolumn into and from the main chamber.

3. The electron microscope of claim 1, wherein said mini-environment comprises a bellows structure for introducing and extruding said minicolumn into and from the main chamber.

4. The electron microscope of claim 1, wherein said mini-environment comprises an evacuation outlet.

5. The electron microscope of claim 1, wherein said mini-environment comprises a second chamber having an opening into said main chamber, and a valve structured for hermetically sealing said opening.

6. The electron microscope of claim 5, wherein said valve comprises a sealing plate anchored to a pivot and movable in the Z-direction.

7. An electron microscope, comprising:

a main vacuum chamber housing a stage therein and connected to a vacuum pump;

a load lock for loading specimen into said main chamber; and,

a minicolumn positioned inside said main chamber.

8. The electron microscope of claim 7, further comprising a back plate attached to said main chamber, and wherein said minicolumn is connected to the back plate.

9. The electron microscope of claim 7, further comprising at least one tilted minicolumn situated inside said main vacuum chamber at a tilt with respect to the miniocolumn.

10. The electron microscope of claim 9, wherein said tilt is variable.

11. The electron microscope of claim 7, further comprising a vacuum pump situated inside the main vacuum chamber and connected to the minicolumn.

12. An electron microscope, comprising:

a main vacuum chamber connected to a vacuum pump and housing:

a turntable stage;

a holding arm; and,

a minicolumn attached to said holding arm.

13. The electron microscope of claim 12, further comprising a radial pivot, and wherein said arm is connected to said radial pivot.

14. The electron microscope of claim 12, further comprising a linear motion carriage, and wherein said arm is connected to said linear motion carriage.

15. The electron microscope of claim 12, further comprising at least one additional minicolumn connected to said holding arm.

16. The electron microscope of claim 15, wherein said at least one additional minicolumn has a tilt with respect to the minicolumn.

17. The electron microscope of claim 16, wherein the tilt is variable.

ABSTRACT

A charged particle beam microscope is described, which is equipped with a minicolumn. Various embodiments are disclosed suitable for various uses. According to one embodiment the minicolumn is situated inside a mini-environment and can be introduced and withdrawn from the main vacuum chamber. According to other embodiments, the minicolumn is situated inside the main vacuum chamber. According to further embodiments, a turntable stage is used and the minicolumn is attached to an arm movable in the radial direction of the turntable.

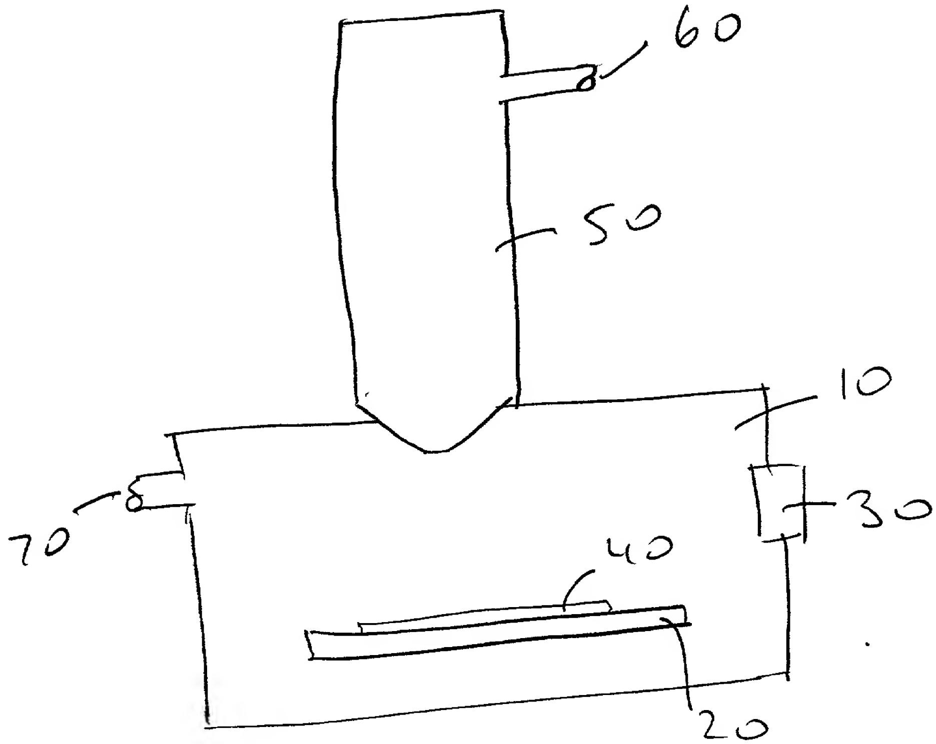

Fig 1

PRIOR ART

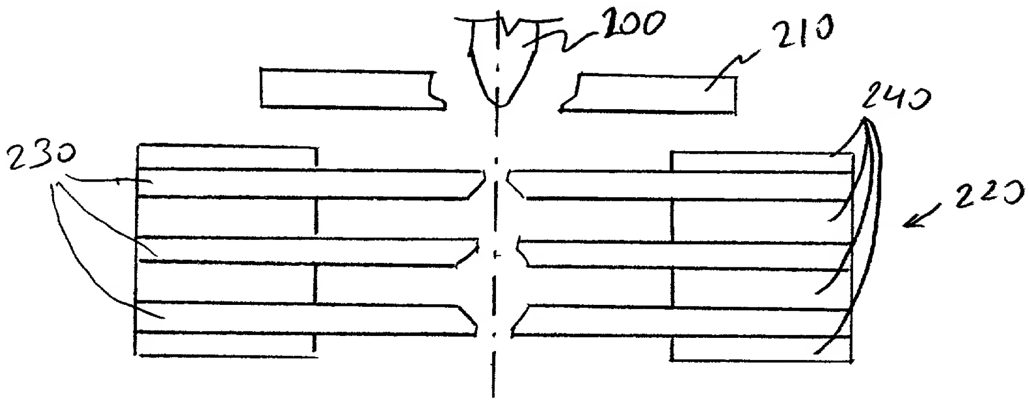

Fig 2

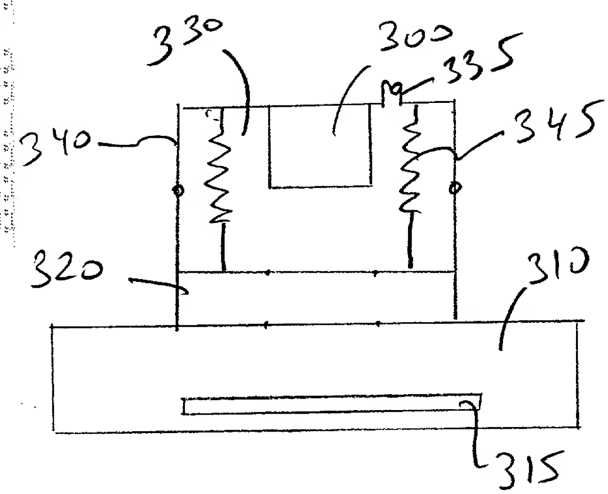

Fig 3A

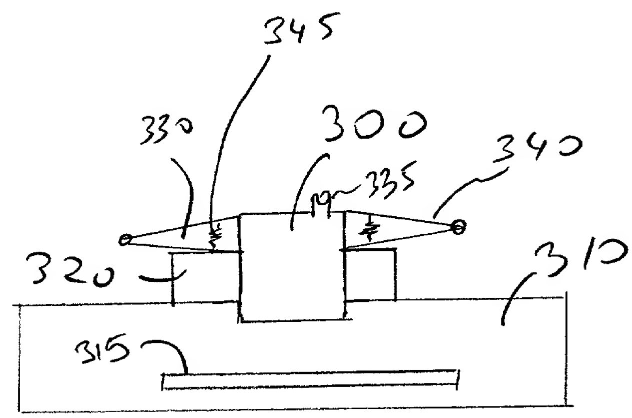

Fig 3B

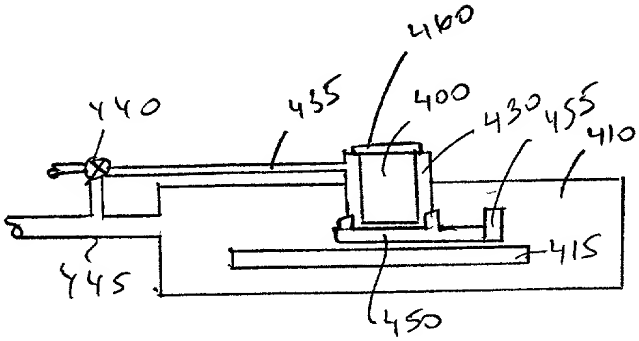

Fig 4A

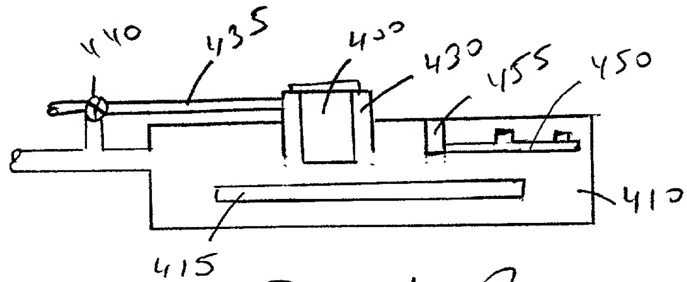

Fig 4B

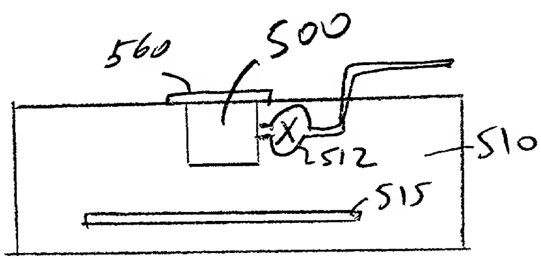

Fig 5A

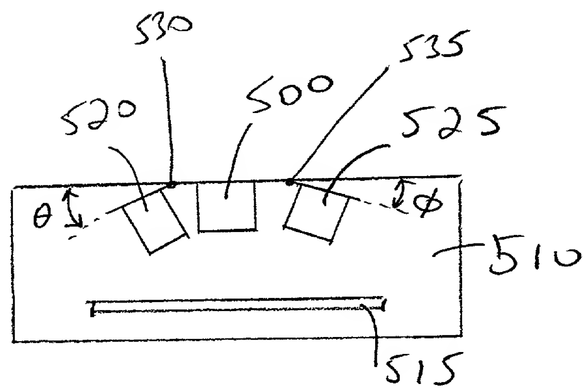

Fig 5B

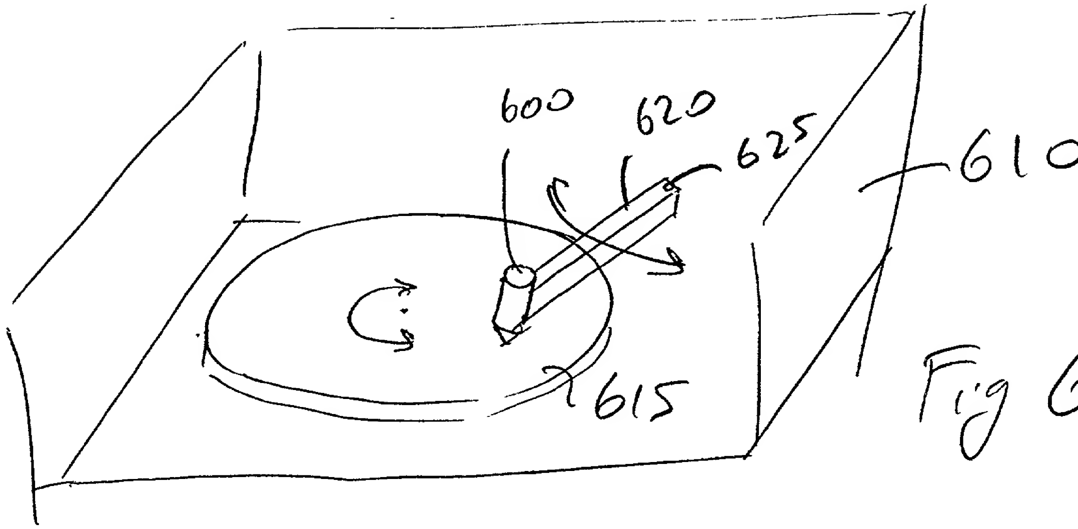

Fig 6A

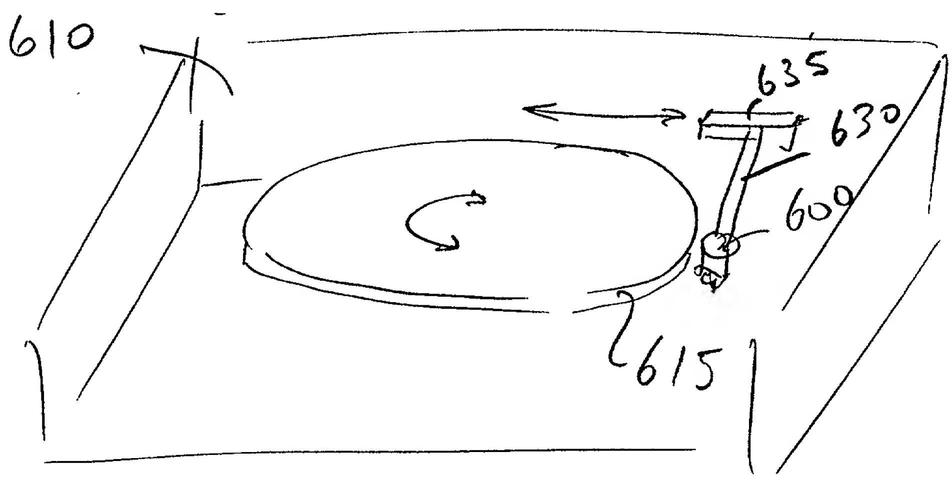

Fig 6B

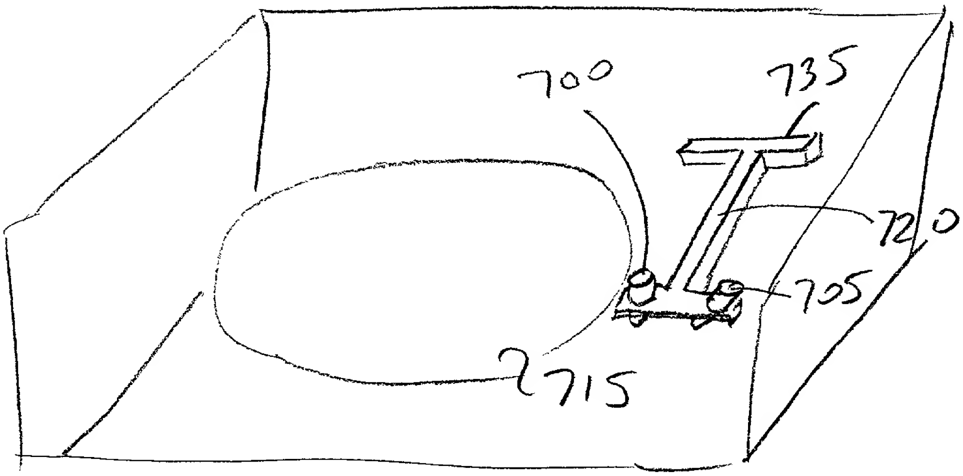

Fig 7A

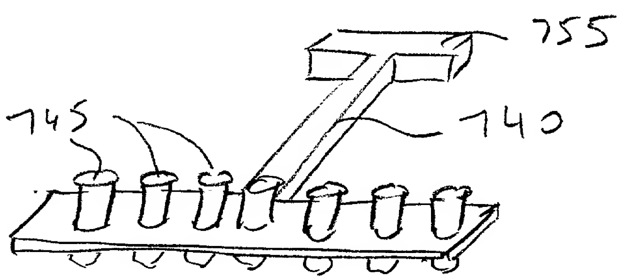

Fig 7B

Atty. Dkt. No.2935/PDC/ICT/JB

COMBINED DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

This declaration is of the following type:

[X] original
[ ] divisional
[ ] continuation
[ ] continuation-in-part

INVENTORSHIP IDENTIFICATION

My residence, post office address and citizenship are as stated below next to my name. I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

TITLE OF INVENTION

"CHARGED PARTICLE BEAM MICROSCOPE WITH MINICOLUMN"

SPECIFICATION IDENTIFICATION

The specification of which:

[X] is attached hereto
[ ] was filed on , under Serial No. , executed on even date herewith; or
[X] Express Mail No.TB907846676US(as Serial No. not yet known)
and was amended on ________________ (if applicable)
[ ] was described and claimed in PCT International Application
No.____________________ filed on ________________ and as amended under PCT Article 19 on ________________.

ACKNOWLEDGMENT OF REVIEW OF PAPERS AND DUTY OF CANDOR

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose all information I know to be material to patentability in accordance with
Title 37, Code of Federal Regulations, §1.56,

and which is material to the examination of this application; namely, information where there is a substantial likelihood that a reasonable Examiner would consider it important in deciding whether to allow the application to issue as a patent, and

[X] In compliance with this duty there is attached an Information Disclosure Statement in accordance with 37 CFR §1.98.

PRIORITY CLAIM (35 U.S.C. §119)

I hereby claim foreign priority benefits under Title 35, United States Code, §119, of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below, and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed.

[X] No such applications have been filed.

[ ] Such applications have been filed as follows:

A. Prior foreign/PCT application(s) filed within 12 mos. (6 mos. for design) prior to this application, and any priority claims under 35 U.S.C. §119

Country/PCT	Application No	Date Filed	Priority Claimed
			[ ] Yes [ ] No
			[ ] Yes [ ] No
			[ ] Yes [ ] No

B. All foreign application(s), if any, filed more than 12 mos. (6 mos for design) prior to this
U.S. application

Country:
Application No:
Filing date:

PRIORITY CLAIM (35 U.S.C. §120)

I hereby claim the benefit under Title 35, United States Code, §120, of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose information that is material to the examination of this application (namely, information where there is substantial likelihood that a reasonable Examiner would consider it important in deciding whether to allow the application to issue as a patent) which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application.

[X] No such applications have been filed
[ ] Such applications have been filed, as follows:

	Status			
Serial No.	Filing Date	Patented	Pending	Abandoned

POWER OF ATTORNEY

I hereby appoint the following attorneys and/or agents to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

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DECLARATION

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and, further, that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Sec. 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patents issued thereon.

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(Declaration ends with this page)